EAF ENERGY OPTIMIZATION AT NUCOR YAMATO STEEL

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SUMMARY

This document will outline and focus on the use of chemical energy in the Electric Arc Furnaces at Nucor Yamato Steel Arkansas (U.S.A.). The paper will describe some of the technologies adopted, such as the use of MODULE oxygen and carbon injection technology, foamy slag practices and post combustion. A mass and energy balance is presented, an overview of these results will also be presented and discussed. Nucor Yamato Steel, located in Blytheville (Arkansas-USA), has an annual capacity of 2,800,500 stons. The annual capacity includes the production of structural steel (hot rolled wide flange structural steel shapes, standard channel and miscellaneous channel shapes, angle, car building shapes, H-piling and hot rolled steel sheet piling sections). The meltshop operates two 150 ton (charge tons) AC EAFs, the nominal diameter of the furnace is 22ft (6700mm), melting transformer rated 90 MVA each having an average active power input of 78 MW.

KEYWORDS

- oxygen and carbon injection technology
- chemical energy
- energy and mass balance

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ENERGY AND MASS BALANCE

A mass and energy balance was performed so as to enhance the knowledge of:

- Furnace Energy Flows
- Furnace Mass Flows
- Carbon-Oxygen Balance
- Chemical Reactions and Furnace Efficiency
- Total Flue Gas Volume
- Volume of Air Ingress into the Furnace

The exercise serves as an analytical tool for process analysis, optimization and evaluating benefits of better energy efficiency versus operational costs.
The energy balance was calculated for varying conditions, such as different injection profiles, (i.e., varying the intensity of firing at different stages of the melting cycle, operating at different stoichiometric ratios, and varying the amount and rate of injected carbon), varying scrap mixes and steel chemistry analyses. Hence the effect of an operational change and the impact on performance could be realized and quantified.
Table 1 below defines the energy balance presented in this paper, which represents average data from 1000 heats of operation on EAF#1.

Table 1. - Definition of Energy Balance

	Short ton	Metric ton
Charged Scrap	136ston	123MT
Yield	92.0%	92.0 %
Steel	125 ston	113MT
Electricity	312 kWh/ston	343 kWh/MT
Charge Coke	2000 lbs/heat	907 kg/heat
Injected Coke	3500 lbs/heat	1588 kg/heat
Slag Volume	8.86ston	8.04MT
Slag FeO %	30.0 %	30.0 %
Natural gas	300 scf/ston	9.37 Nm3/MT
Oxygen	1430 scf/ston	44.64 Nm3/MT

The following assumptions were made:

- Tap Temperature remains constant at 2970 °F – 1632 °C for all conditions.
- Yield remains constant at 92.0%.
- Tap carbon at 0.050%
- Carbon in scrap remains constant at 1185 lbs/heat – 538 kg/heat.
- Hi-Cal lime and dolomite lime charged remains constant at 7800 lbs/heat – 3538 Kg/heat.
- Power on Time remains constant at 29.0 minutes.
- Off-Gas contains 350 lbs/hr – 158 Kg/hr of carbon monoxide.
- Heat Transfer to bath is at 100% efficiency for slag formation and oxidation of carbon, silicon and manganese
- Electrode Consumption constant at 3.01lbs/ston – 1.37 Kg/ston.
- As input energy the gross heating value for the combustion of coke was used.

Table 2 - Scrap Mix and Slag Analysis.

Slag Chemistry	
CaO	32%
SiO2	15%
FeO	30%
Cr2O3	1%
MnO	5%
MgO	11%
Al2O3	6%
P2O5	1%

Scrap Mix	%
Shredded	36.9
#2 HMS	27
#1 HMS	11.9
Pig Iron	5.8
Home Scrap	6.8
Turning	5.5
#2 Bundle	3.4
Pit Scrap	2.7

EAF REACTIONS CONSIDRED

Table 3 below shows the Gross heating value for each element. All reactions below are exothermic, hence there is a release of heat during the reaction. All require pure oxygen with minimum air infiltration. Oxygen usage averages 1430scf/ston – 44.64 Nm^3/MT on EAF#1. This oxygen allows an increased rate of decaburization and improved utilization of the heats of reaction due to presence of little nitrogen, which absorbs heat Table 3 - Gross Heating Values at 3000 °F – 1648 °C

Reaction	Energy	Unit
$C + O_2 = CO_2$	-4.13	kwh/C-lb
$Si + O_2 = SiO_2$	-3.93	kwh/Si-lb
$Al + 3/4O_2 = Al_2O_3$	-3.91	kwh/Al-lb
$CO + 1/2O_2 = CO_2$	-3.02	kwh/C-lb
$C + 1/2O_2 = CO$	-1.11	kwh/C-lb
$Mn + 1/2O_2 = MnO$	-0.89	kwh/Mn-lb
$P + 5/4O_2 = 1/2(P_2O_5)$	-3.06	kwh/P-ib
$Cr + 3/4O_2 = 1/2(Cr_2O_3)$	-1.42	kwh/Cr-lb
$Fe + 1/2O_2 = FeO$	-0.61	kwh/Fe-lb
$CH_4 + 2O_2 = CO_2 + 2H_2O$	-0.29	kwh/CH4-cft
$2CaO + SiO_2 = Ca_2SiO_4$	-0.26	kwh/CaO-lb
$3CaO + P_2O_5 = Ca_3P_2O_8$	-6.02	kwh/P2O8-lb

Table 3

ENERGY INPUT

Electrical Energy to each furnace is provided via transformers rated at 90 MVA, 1100 Volts. Depending on the scrap mix, the appropriate power program is selected which dictates the voltage levels, impedance set-points, stability ranges and electrical power input for the different stages (Bore-In, Melting, Refining, End of Heat) of the meltdown cycle. For the data presented in this paper operations were at 980 V with an additional 1.5 ohm series reactor in the circuit for the first 6000 kWh (maximum) of both charges. Electrical Energy input averages 312KWhton.

Table 4 below shows the various energy inputs. When calculating coke oxidation, the 0.050% of carbon that remains in the steel, (152 lbs/heat - 69 kg/heat) and the remaining 350 lbs/hr -158 Kg/hr of CO in the off gas (48 lbs/heat-22 kg/heat), for the tap-tap time (37.0 mins) was treated as losses to the overall coke oxidation.

About 2.0% of Turnings Oil Burning Energy (10kWh/ton) was accounted for as energy input. Assuming that 80.0% of the FeO is made in the furnace, the formation of FeO from the oxidation of iron accounts for 16 kWh/ton of the total 50 kWh/ton energy generated from the refining reactions, (metal oxidation) in the steel, the largest contributor. For the other metal oxidation reactions, data from the slag analysis presented in Table 2.0 was used in conjunction with the assumptions that 90.0% of the MnO and Cr_2O_3 was made in the furnace, 60.0% of the Al_2O_3 also made in the furnace and scrap P reacts to produce P_2O_5. Reactions (xi) and (xii) in Table 3.0 were considered for the energy release associated with slag formation (11 kWh/ton). Figure 1, shows that 54.0% of our total energy input (366 kWh/ton) is chemical energy.

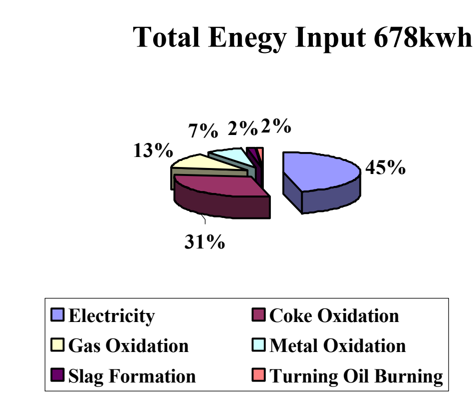
Table 4 - Energy Inputs

Enegy Input	kwh/ton
Electricity	312
Coke Oxidation	207
Gas Oxidation	88
Metal Oxidation	50
Slag Formation	11
Turning Oil Burnin	10
Total 678kwh	678

Description of Coke

	kwh/ton
Charge Coke	58
Inject Coke	104
Electrode Oxidatior	12
Scrap Carbon	39
Total	214

Figure 1 - Chart of energy inputs by percentage



Energy Output into the steel was calculated for an average tap temperature of 2970 °F-1632 °C. Energy retained in the slag approximated to (51 kWh/MT), at a temperature of 3070 °F-1688 °C and 8036 kg –8.86 tons of slag generated per heat.

Losses to the off-gas are highly dependent upon the efficiency of energy transfer to the steel and the rate of energy input. Higher energy input rates demands higher energy transfer efficiencies. As burner efficiencies and heat transfer to scrap metal, decreases over the meltdown period, the gases leaving the furnace becomes hotter, hence the sensible heat load in the gases will increase. Of greater concern should be the CO remaining in the off-gas that has not been oxidized in the furnace, as this represents a relatively large potential energy source (calorific heat) for the furnace. Table 5 shows that the heat of combustion of CO to CO_2 is three times greater than the heat of combustion of C to CO. Provided that the CO can be burned in the furnace, there will be a significant reduction in the heat load to the off-gas.

Note however from a heat transfer efficiency standpoint combusting C to CO transfers a higher percentage of its reaction heat to the scrap or bath than the combustion of CO to CO_2. In the case of C to CO, burning occurs within the scrap pile or bath, so the evolving CO gas has more intimate contact with the steel, typical of a carbon boil, whereas the combustion of CO generally occurs above the scrap pile.

Table 5.0 lists the Energy Outputs and Figure 2.0 depicts the overall percentage each contributes.

Energy losses of the off-gas, at the fourth hole (206 kWh/MT) comprises of:
1. Gas energy at spark arrestor, (107 kWh/MT)
2. Heat loss from duct (7.0 kWh/MT).
3. Cooling water losses for Duct (93.0 kWh/MT).

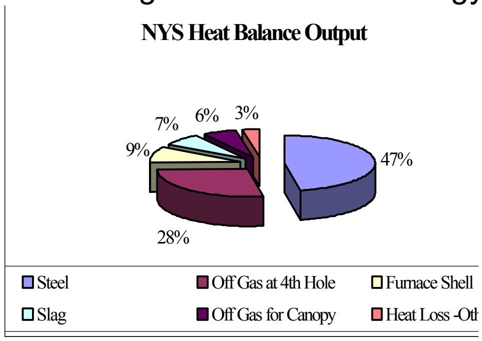
Energy output of the Furnace shell (68.0 kWh/MT) comprises of:
1. Cooling water for sidewall (19.0 kWh/MT).
2. Water for Roof and 4th hole elbow (46.0 kWh/MT).
3. Heat loss from furnace bottom (2.0 kWh/MT).

Heat losses that were not accounted for via calculations were placed under the category, “Heat loss for other”. Some of the contributing factors include errors in calculations, cooling water for the More MODULES which were not considered, an over-simplified model of radiate heat losses and radiation losses when the roof is open.

Table 5 - Energy Outputs

NYS Heat Balance Outpu	kwh/ton
Steel	320.2
Off Gas at 4th Hole	187
Furnace Shell	61.4
Slag	46.5
Off Gas for Canopy	41.5
Heat Loss for Other	21.2
Total	**678**

Figure 2 - Chart of Energy Outputs by Percentage



MODULE TECHNOLOGY AND OXY-FUEL BURNERS

Figure 4 below shows the injection equipment configuration on EAF#2. Four MORE MODULES (Duct, Sump and Lance North and Lance South) and two PTI oxy-fuel burners (Sump and Lance), this represents a total of 10 oxy-fuel burners, 0.282 MW of burner rating per ton of furnace capacity. During the melting cycle the MORE MODULES cycles automatically between the burner mode and the supersonic oxygen/carbon injection mode.

Initially oxy-fuel burners were first used to provide heat to the cold areas of the furnace, typically at the slag door, between the phases and around the tap hole for eccentric bottom tapping (EBT) furnaces. They allowed more uniform melting of the scrap charge, hence the melting time to reach the flat bath stage decreased and so productivity increased.

The majority of heat transfer arises from chemical reactions that generate gases.

The modes of heat transfer are via:

1. Forced Convection from combustion products.
2. Radiation from the Combustion products. The amount of heat transfer to the scrap is a function of the temperature difference between the load and burner flames and the exposed surface area of the scrap.
3. Conduction from metal oxidation, carbon oxidation. This type of heat transfer takes place in the presence of excess oxygen, almost all of this generated heat in the case of iron oxidation is transferred to the scrap since the iron oxides remain in the furnace. This however is not generally a good practice as it results in lower yields.

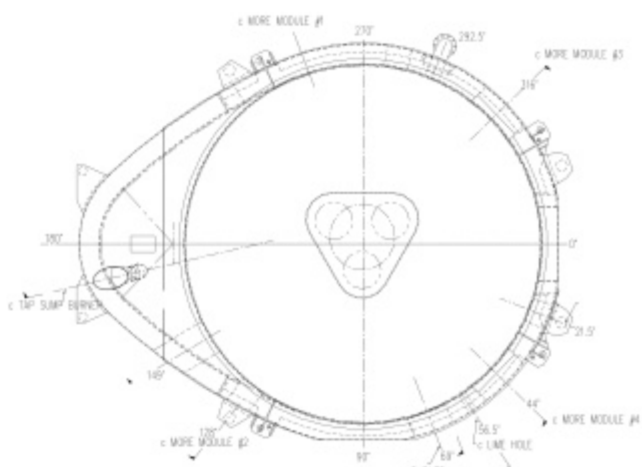


Figure 4 – MORE Modules and Two Burner Positions.

MORE MODULE TECHNOLOGY

The decision to install the MODULE technology was justified by the productivity increase and lowering of transformation costs that the new oxygen and carbon injection generation technology could provide. On EAF#2 a set of MODULE injectors began operation in September 1999.
Due to the overwhelming positive results and performances achieved on EAF#2, Nucor Yamato Steel decided to install the technology in EAF#1. The MODULE Injection Technology basically adds thermal energy over and above the electrical energy. The thermal energy is obtained by a chemical reaction that uses the foamy slag to transfer the heat into the lower liquid steel. The innovation is based on the principle of obtaining thermal energy, created by the high efficient combustion of injected oxygen and carbon according to recipes suited to the tapping steel grade. Such energy is transferred effectively to the scrap, during melting, and then to the liquid steel. The utilization of the thermal controlled energy allows optimizing the whole EAF metallurgical process, as:

- The thermal energy released is applied to the entire furnace;
- The electric arc becomes more stable and efficient;

The metallurgical process generated by the MODULE Technology reduces the excessive turbulence and does not require localized “over-oxidation” in the bath, maintains composition homogeneity during meltdown, especially for large- sized furnaces.

MODULE TECHNOLOGY EQUIPMENT

Oxygen and carbon injectors:

Fig. 5 - MODULE Inside View

Fig. 6 – MODULE Outside View

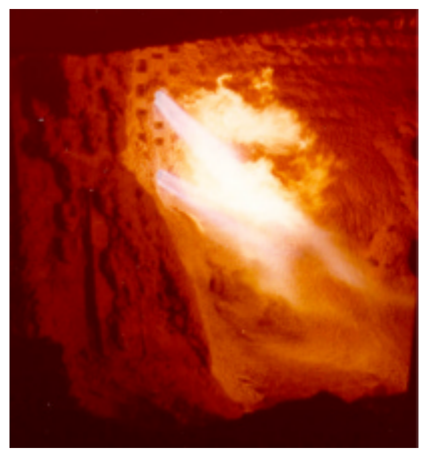


Fig. 7 – MODULE In Burner Mode

Oxygen and natural gas valve trains

Dedicated valve trains have been provided to regulate and control independently injected oxygen and natural gas. Both EAFs have an independent train for the oxygen lines and a train is for the natural gas.

Carbon Dispensers

On both EAF#1 and EAF#2, are equipped with three new carbon dispensers MOCA, sulpplied by MORE, to satisfy the needs of the MODULE Technology.

Automation and Control System

The operating and monitoring system for the MODULE Technology is “user friendly” and allows a fully automated operation of the process. The working sequences are totally independent from the manual operation; subsequently the EAFs operators only supervise the process
Different working recipes (oxygen, natural gas, carbon flow rates, set points, start/stop, etc.) are programmed in relation to different scrap mixes to optimize the entire melting and refining process and to balance the different fix carbon scrap content.

BURNER ENERGY

The furnace is charged twice, the first charge being 90 sTon at an average melting power of 79 MW; the second charge of 46 Ton is at an average melting power of 80 MW.

Varying burner profiles are employed depending on scrap charge composition. Each MODULE unit may also have a different burner firing profile and oxygen-carbon injection rates. The profiles are set up for both charges on a heat. The stoichiometric gas-oxygen ratios, gas set-points, oxygen and carbon flow set-points can be inputted for fixed kWh ranges.

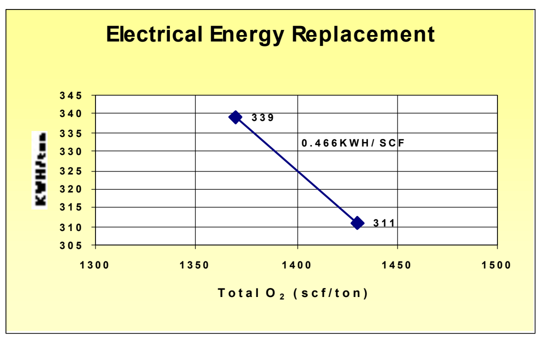
This allows a tremendous degree of flexibility in that burner heat input, oxygen use and carbon injection can be controlled at all stages of the melting cycle.

At our present profiles, MORE MODULES and PTI burners consume an average of 300 scf/ton – 9.37 Nm^3/Mt of natural gas and 1430 scf/ton - 44.64 Nm^3/ton of oxygen, for an average power on time of 30.45 minutes (39000 kWh). Note this oxygen consumption includes injection oxygen.

Overall each furnace generates 88 kWh/ton of burner power. Comparative studies, reports 32 kWh/ton of burner power to eliminate cold spots in a UHP furnace and 55-91 kWh/ton of burner power for low powered furnaces.

Actual performance data shows that there was an average decrease of 28 KWH/ton in electrical power consumption. The average energy replacement amounts to 0.466 kWh/scfO_2 – 16.4 kWh/Nm^3O_2 as depicted in Figure 14 below. During production, lancing operations cannot be isolated, so this number also reflects oxygen from the MORE OXYGENJETS injectors. Power on time reduced by 7.0%, causing the productivity rate per hour to increase by 8.0% (200 Ton/hour). There has also been a recordable decrease in electrode breakage due to fewer scrap cave-ins.

Figure 14 - Electrical Energy Replacement For Burners



The benefits of MODULES when operating in oxygen-carbon injection will be discussed in following sections.

OXYGEN INJECTION

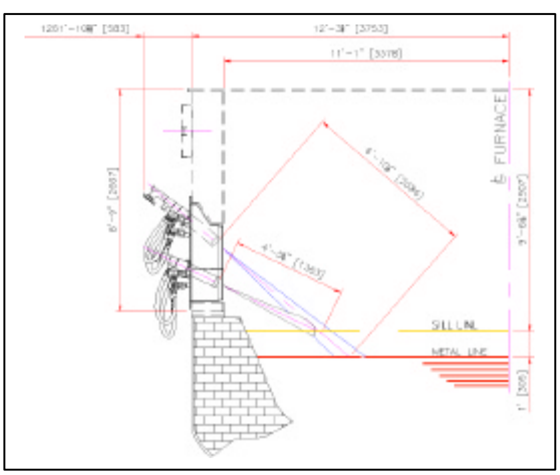


Fig. 15 - Injectors Section Lay-out

In the steel-making process oxygen usage plays an integral role in various activities. It is involved in scrap cutting, melting, foamy slag practices, decaburization and post-combustion. Oxygen affects energy input and process metallurgy (lower ppm levels of N_2, temperature and composition homogeneity of the bath), hence its importance to overall process optimization efforts.

Oxygen is injected via the MORE MODULES. refer back to Fig. 4 which shows the configuration of these modules. The MODULES injection units, excluding the two PTI burners consumes 785 scfO_2/ton – 22.8 Nm^3O_2/ton, this includes the oxygen required for combustion of gas and oxygen that is injected towards the end of each charge. On average, 360 scfO_2/ton – 10.1 Nm^3O_2/ton, of the total 785 scf/ton – 22.6 Nm^3O_2/ton of oxygen, used by the MODULES for injection oxygen.

The total oxygen usage over the entire heat is 1430 scfO_2/ton – 44.6 Nm^3O_2/ton.

The implementation of the MODULES has allowed multiple points of injection, much more effective penetration into the bath and uniform distribution of lancing oxygen. With just a few points of injection, limitations on the amount of oxygen that can be injected, localized over-oxidization, and splashing are potential problems.

The installation of the MORE MODULES has allowed the complete removal of all lances the BSE consumable lance manipulator at the slag door and more recently the Berry lances. The MODULES are designed with no moving parts, consumable pipes or tips. Inherent in its design the maintenance costs are much lower, with the availability and reliability higher when compared to the previous lance manipulator. The slag door remains closed for the entire melting period reducing the amount of ingress air and decreasing the off-gas system evacuation requirements. Other positive factors, are the energy savings gained with less ingress air and the possible reduction in $NO_{x.}$ Ingress air contains 78.1% nitrogen, therefore the greater the volume of ingress air, the greater the volume of nitrogen, which will require a greater amount of energy to heat up from ambient to off-gas temperature.

The OXYGENJET injector is located above carbonjet injector at 3ft-6in above the metal bath at angle of inclination 43º below the horizontal, figure 15 which shows the injectors section lay-out. When operated in the supersonic mode it allows decaburization and deals with any high carbon melt-ins. The CARBONJET is at a much shallower angle of 27º, hence during operation, the O_2 stream impinges the carbon jet stream above the steel bath, allowing complete combustion of the injected carbon and providing a favorable environment for the conversion of CO to CO_2.

These angles of inclination affect bath penetration an important factor in ensuring that reactions are taking place in the steel bath. Lance flow rates and lane angles controls the position and magnitude of the splash. Finding the optimum angle that is not too steep nor shallow is necessary to avoid turbulent slag splashing, increased refractory wear, clearing of the slag layer which exposes the bath to oxidation and increases its susceptibility to nitrogen (monatomic $\underline{N}$ dissolves) pickup.

Oxygen is lanced throughout the heat, in an effort to reduce the frequency of high CO peaks in the off-gas as well as minimize those peaks. A 7-10 ton hot heel is maintained in the furnace. The intent is to achieve a lower more continuous flow rate of CO in the off-gas coupled with reducing the evacuation requirements of the DEC (Direct Evacuation Control system).

The oxygen injection capabilities of the MORE MODULES gives the furnaces the ability to achieve high melting rates. Higher melting rates and decreased refining times have resulted in a reduction of heat losses, hence further energy savings in the furnace.

Many challenges are presented when attempting to optimize oxygen usage; some of the more important issues are outlined below. Attention must be paid to the oxygen-carbon balance when attempting to increase oxygen rates and must be balanced with increased carbon, else negative energy benefits accompanied by low yields will result as the slag becomes supersaturated in FeO. Elevated concentrations of FeO also reduces the viscosity of the slag, adversely affects foaming, decreases heat transfer efficiencies, decreases basicity which affects phosphorous removal and increases the demand of MgO as the solubility of the MgO in the slag increases.

When increasing oxygen lancing rates the generation of additional gas volumes and heat loads must be considered, as it affects the loading and performance of the evacuation systems. The amount of CO generated in the gas is much higher, hence the chances of fugitive CO emissions in the meltshop becomes greater, resulting in environmental compliance and safety issues.

CHARGE AND INJECTION CARBON.

Charge and injection carbon contributes a significant amount of energy (162kWh/ston) to Nucor Yamato's steel-making process by the oxidation of carbon resident in the bath and by combustion of carbon that does not go into solution in the steel bath.

Carbon will also generate CO as it reacts with oxygen. This CO helps with foamy slag practices, and reduces the amount of ingress air into the furnace.

Charge carbon is added to the furnace via the scrap bucket; on average 2000lbs/heat - 907 Kg (15 lbs/ston-6.8 Kg/sTon) of charge carbon is added per heat. The amount of charge carbon used is based on the desired < 0.050% C at tap, an estimated carbon content of 1185 lbs/heat–538 kg/heat in the scrap, a desired 20-30% FeO (recovery of iron units) in the slag and a projected oxygen consumption of 1430 scf/ton - 44 Nm^3/MT. In essence the total carbon used correlates to a calculated carbon-oxygen balance.

Carbon is injected through the MORE MODULE Carbonjet at an average rate of 26 lbs/ston – 11.8 Kg/ton (3500 lbs/heat - 1429 Kg/heat).

Charge carbon in the steel allows an aggressive carbon boil when the oxygen is injected into the steel. The CO gas as it bubbles through the steel removes nitrogen, hydrogen and oxide inclusions reducing it to acceptable levels. The violent boil will also promote slag-metal contact enhancing desulfurization capacity.

The CO above the bath also provides another source of chemical energy, as it can be post-combusted with oxygen to release further heat.

Trials of reducing charge carbon and achieving final bath carbon in an effort to improve the degree of combustion continue to be challenging.

Balancing carbon injection at the slag level to control the FeO content of the slag, presents another area of focus, in improving our yields.

Undoubtedly the benefits and importance of carbon cannot be questioned, but its impact on CO_2 emissions and environmental compliance must not be overlooked. Extracting data presented by Geiger, the combustion of coal releases 266.67 lbs CO_2/MMBtu – 121 Kg CO_2/MMBtu.

SLAG FOAMING

Good foamy slag increases electrical efficiency because of more efficient heat transfer from the arc (energy transfer efficiencies as high as 90.0% have been reported). At the beginning of the melt, electrical efficiency is quite high, as the scrap shields the arc. The electrical efficiency begins to drop as scrap melts and the shield is lost. A good foamy slag shields the arc, reduces the amount of heat that is radiated to the walls of the furnace, thus the heat transfer to the bath increases. Slag foaming allows us to melt the steel at higher power factors (longer arcs) hence increasing electrical energy input (80 MW) without the risk of furnace roof and shell damage.

Some of the other benefits are outlined below:

- Reduced Melting Time
- Reduced Electrode Consumption (lower I^2t)
- Reduced Refractory Consumption.
- Decreased Flicker.
- Reduced Noise.
- Increased Productivity.
- Improved Quality, as it absorbs more deoxidization products.
- Decreased absorption of nitrogen and hydrogen.

A V - ratio (Cao/SiO_2) of 2.0 – 2.2 is maintained by the addition of hi-cal and dolomitic lime, on average lime addition amounts to 7800 lbs/heat-3538 Kg/heat. As the scrap mix varies, lime addition

amounts are adjusted to compensate for the variances in Si, Al, P, Mn, all of which contribute acidic oxides to the slag reducing its basicity.
Slag basicity is one of the major factors considered when attempting to optimize slag foaming, it affects the viscosity of the slag, (the greater the basicity the more viscous the slag becomes), the solubility of MgO (increasing basicity decreases MgO solubility), the solubility of FeO, (FeO solubility increases in higher silica slags) and refractory wear. As the relative effective viscosity of a slag increases, up to an optimum point (where the amount of second phase particles are not exceeded), the residence time of the CO gas bubbles in the slag is prolonged, extending the stability and life of the foam.

Most of the gas produced is carbon-monoxide from the oxidation of bath and injection carbon via:
$C + 1/2O_2 \rightarrow CO$ ………………………………………………………….(5)
Carbon-Monoxide is also liberated via the reduction of FeO.
$FeO + C \rightarrow Fe + CO$ ……………………………………………………..(6)
There is also a small amount of CO_2 generation from the calcination of residual carbonate in the lime.
The MORE MODULES allows us to have good control of the carbon-oxygen injection at the slag layer hence controlling its FeO content (aim for20-30%). FeO the major fluxing component of the slag greatly affects the viscosity, elevated levels results in a fluid slag, which is difficult to foam, as the retention time of the gas bubbles is too short.
Other factors affecting slag foaming includes MgO content of slag and temperature.
At a V-ratio of 1.7, we target for a 15.0% MgO content, which gives us the ability to foam over a wider composition range of FeO. For a better understanding of FeO and MgO on the phase relationships, Isothermal Solubility Diagrams should be consulted, which is not in the scope of this paper.
Increasing temperature adversely affects foaming properties as the viscosity of the slag is greatly reduced. As the temperature increases, the liquidus curves on a MgO – FeO ISD shifts impacting the phase relations, there is decrease in second phase particles and the slag becomes very fluid, this is usually accompanied by an increase in FeO content.
Consistency of operations is important in achieving a good slag, i.e., frequent slag analyses, maintaining carbon oxygen- balances, melt-in carbon, V-ratios, and constant tap temperatures.

OPERATIONAL RESULTS

The following tables below show some of the operational results on both electric arc furnaces. On EAF#1 the comparative data looks at the period September 2000 - March 2001 (without MORE MODULES) to September 2002 – Present (with MORE MODULES). On EAF#2 the comparative data looks at the period August 1999 – February 2000 (without MORE MODULES) to Sept. 2002 – Present (with MORE MODULES).

		EAF #1		EAF #2	
		Sept. 2000	Dec. 2003	Aug. 1999	Dec. 2003
		Mar. 2001	present	Feb. 2000	present
Scrap buckets	n.	2		2	
Charge weight	stons	142.4	136.0	142.4	136.0
Heat size	stons	123.6	125.4	124.3	125.1
Yield	%	86.7	92.2	90.1	92.0
Active Power	MW	77.8	78.0	74.7	79.0
Power On	min.	32.3	30.9	33.8	30.0
Power Off (no delays)	min.	7.6	7.0	8.3	7.0
Tap to Tap (no delays)	min.	39.9	37.9	42.1	37.0

Electrical Energy (Charge)	kWh/ston	294	286.76	295.5	286.72
Electrical Energy (Cast)	kWh/ston	339	311.0	338.5	311.7
Electrode	lbs/ston	3.44	3.12	3.50	2.90
Total Oxygen	scf/ston	1370	1430	1136	1480
Total Natural gas	scf/ston	266	300	220	313
Total Injected Carbon	lbs/heat	1325	3511	878	3502
Productivity	ston/hour	185.1	198.5	175.8	202.8

CONCLUSION

Optimizing energy utilization in the furnace requires detailed analysis and understanding of all the reactions taking place at every phase of the steel-making process, in order to achieve the right balance of electrical and chemical inputs in the right quantities and at the right times.
A Heat and Mass Balance is a necessary analytical tool that provides an overall view of energy inputs and energy outputs. It has resulted in improved operating efficiencies, more consistent practices, better results and enhanced process knowledge. Our ability to evaluate the benefits of increased energy efficiencies, increased productivity versus operational costs allows us to remain competitive and maintain an advantage in the dynamic market conditions that exist today.

Nucor-Yamato chemical energy input accounts for 54.0% of the total energy input. Auxiliary chemical energy sources currently applied at the facility include:

- MORE MODULE Technology;
- Oxy-Fuel Burners;
- Charge and Injection Carbon;
- Exothermic constituents in the scrap;

Since the implementation of the MORE MODULE Technology and enhanced optimization of the energy profiles during the melting cycle, we have achieved better performance and productivity results. Some of the advantages and disadvantages are summarized below:

- Traditional injection equipment (water cooled and consumable oxygen and carbon lances, side wall burners) is entirely substituted by an effective single piece of equipment. This enormously reduces maintenance requirements and down time associated with traditional lance manipulators.
- Increased production capability (estimated at 2,800,500 tons/year based on an average utilization 87.0% and a furnace productivity rate of 200t/hr). Foamy slag formation is faster and more consistent, allowing optimization of the AMI Impedance Regulators (increased power).
- Reduced production costs. Eliminates Barry lance tip repair/replacement ($400,000.00 annually) and eliminates BSE consumable lance pipe cost ($65,000.00 annually).
- System automation allows the entire process to be constant, repeatable and predictable. Eliminates the possibility of oxygen damage to the furnace from operator error. Operators workload reduced considerably (more time to focus on monitoring regulation system). Entire process is optimized.
- The complete combustion system (MORE MODULES, oxy-fuel burners) could be easily incorporated into the AMI “Smart Arc NT Furnace” control system.
- Lower electrode consumption – Lower power on times, foamy slag formation is faster and more consistent, reducing unshielded arc oxidation of the electrodes.
- Lower Refractory costs – Foamy slag formation is faster and more consistent, reducing damage to refractories from unshielded arc flare. Furnace cycles could possibly be extended to 6-7 weeks (higher furnace utilization and increased productivity).

- Higher Yield (good control of carbon-oxygen balance, increased flexibility). The combustion process by the MORE MODULES is achieved in a single step rather than oxidizing the steel first and then reducing it by carbon (with traditional lance manipulators).
- Off-gas temperatures reduced in the DEC by having the combustion process take place in the slag rather than in the off-gas system (lower CO emissions in the DEC system).
- Off-gas volumes reduced. Slag door remains closed at all times eliminating cold ingress air into the system. More efficient damper control due to less fluctuations of pressure in the furnace (more efficient side draft through the fourth hole as a result).
- Reduces the use of charge carbon. Carbon can be introduced into the furnace through the Carbonjet injector. This allows better control of carbon-oxygen balance, greater influence on yields. Less carbon combustion products are released into the shop atmosphere during charging (reduced dust covering in the furnace area).
- Increased buildup in the drop out chamber.
- Increased wear in 4th hole elbow due to higher off-gas velocity determined by an increased amount of process gas.